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DRIFT PHENOMENA IN THE VICINITY OF DEVIL'S LAKE AND BARABOO, WISCONSIN.[1]

THE study of the drift about Devil's Lake and Baraboo, Wisconsin, has brought out facts and relations of more than local interest, which it is the aim of this paper to state.

Location.—The region is in the central part of the southern half of the state, about thirty-five miles northwest of Madison, and on the western limit of the area covered by the Green Bay lobe of the last great ice-sheet—the ice-sheet which deposited the Wisconsin drift. Since the ice of this epoch advanced as far to the west in this region as that of any earlier epoch, the region concerned is also on the border between the glaciated country to the east, and the driftless area to the west.

General topographic relations.—The accompanying map, Fig. 1, shows the surroundings of the region especially concerned, and Fig. 2 the topography of a small area about Devil's Lake. Extending in a general east-west direction and rising 500 feet to 800 feet above the surrounding country, is the great Baraboo quartzite range (shaded area Fig. 1) in which Devil's Lake (*a*) is situated. This range, and especially the larger range to the south, is the most prominent topographic feature of the region, and, as will be seen, had not a little influence on the behavior of the ice at its margin. Devil's Lake divides the range into an eastern and a western portion, known respectively as the east and west bluffs (or ranges). The highest point of the range, about four miles east of the lake, has an altitude of 1620 feet. The eastward extension of the west range (see Fig.

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[1] This paper is based on work done in connection with the field course in geology in The University of Chicago. Other students than those whose names appear in connection with this article, had something to do with the development of the facts here set forth. This is especially true of Messrs. H. R. Caraway, E. C. Perisho, D. P. Nicholson, L. Wolff and O. J. Arnold.

2), lying south of the lake, and popularly known as the "Devil's Nose," has an elevation of 1500 feet.

North of the main range there is a lesser ridge of quartzite, more or less interrupted, rising 300 feet to 500 feet above the Baraboo River, and reaching its greatest prominence at the "Lower Narrows" of that stream (*b*, Fig. 1). Between these quartzite ranges is the capacious valley, partly filled with drift, through which the Baraboo River flows.

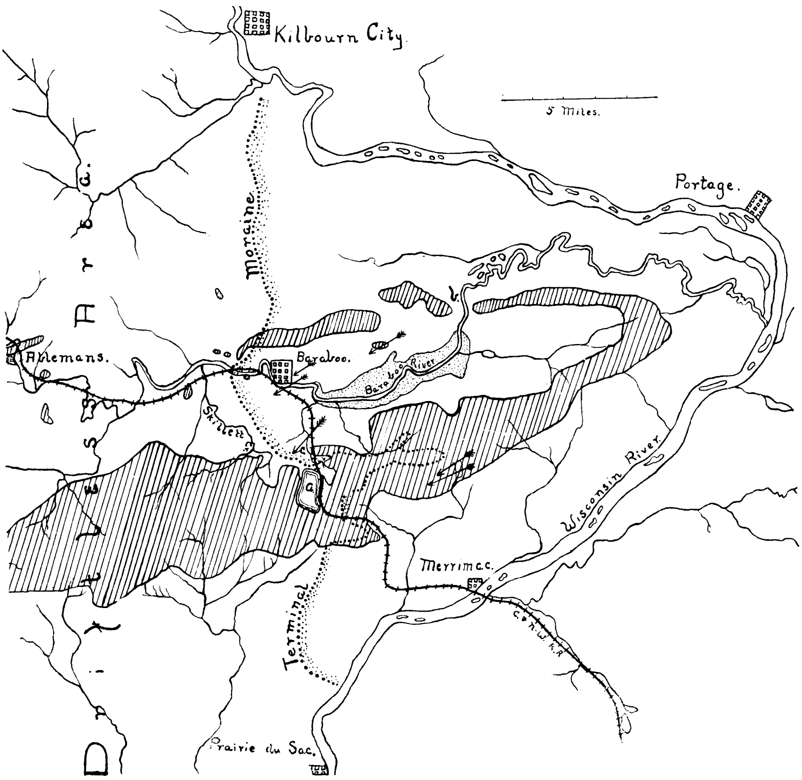

FIG. 1. Map of the area about Baraboo and Devil's Lake. The shaded area is quartzite. The unshaded area is underlain by Potsdam sandstone.

About the quartzite ranges, and within the area covered by the ice, the surface is marked by those varied features which usually affect the surface of a region heavily covered with drift.

West of the limit of the ice, the topography is equally characteristic of the driftless area, though modified along the flats by the deposits of the glacial drainage.

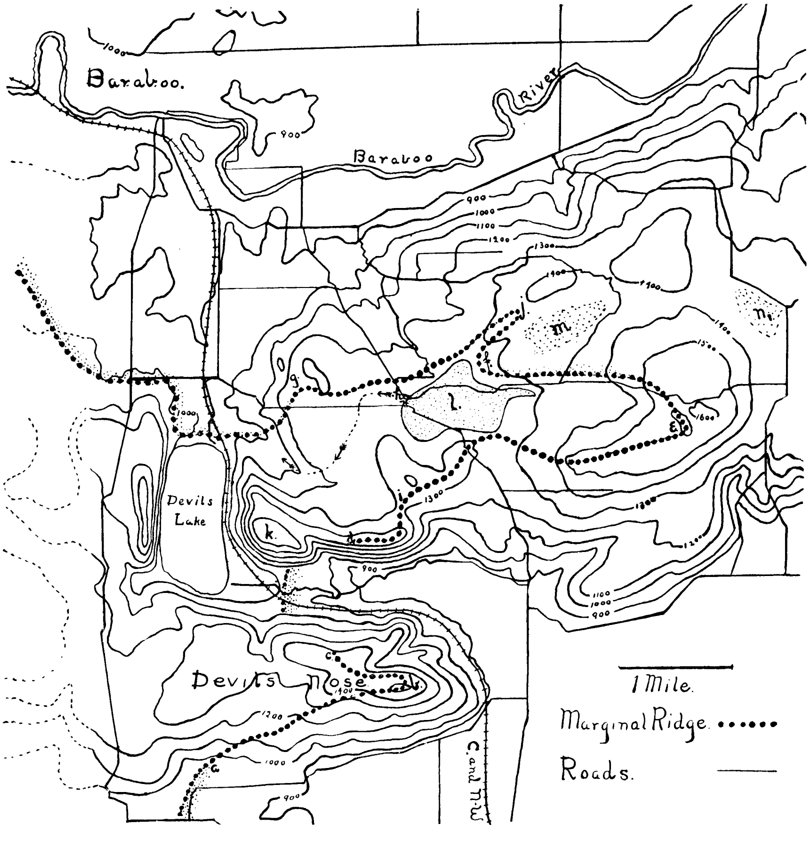

FIG. 2. Topographic map (contour interval 100′) of a small area about Devil's Lake, taken from the Baraboo sheet of the U. S. Geological Survey. The dotted western continuations of the contours represent extensions of the contours beyond the published map.

Ice movement.—From the course of the striæ, it is known that, as the ice advanced into this region, its general direction of motion was west-southwest. This is in accord with the general direction of movement in the western portion of the Green Bay lobe. The location and direction of recorded striæ appear on the map shown in Fig. 1. With but one exception they vary from W. 20° S. to W. 30° S. The exceptional direction, W. 60° S., is found on the north side of the main quartzite range (*c*, Fig. 1), where the normal deploying of the ice was prevented by the steep face of the bluff. It illustrates the tendency of glacier ice to move in a direction essentially at right angles to its margin.

The terminal moraine.—The limit of the ice advance is marked by a well defined terminal moraine, the outer margin of which west of the Wisconsin River is shown on the accompanying map (Fig. 1). Swinging southward from Kilbourn City in in gentle curves, it turns westward in the great valley between the quartsite ranges, and then loops back to the east along the north face of the quartzite range *nearly seven miles* before crossing it. Across the crest of this range it turns promptly to the west in the valley between the east range and the Devil's Nose. About the elevation which bears this name, the moraine again loops back to the east, and after rounding the "Nose" turns promptly to the west. After following this direction for about two miles, it turns southward, reaching the Wisconsin River about seven miles below Merrimac.

On the low lands, the terminal moraine has the characteristics which usually affect such formations. In width it varies from half to three-quarters of a mile. Approached from the west, that is, from the driftless side, it is a somewhat prominent topographic feature, often appearing as a ridge thirty, forty or even fifty feet in height. Approached from the opposite direction it is notably less prominent, and its inner limit, wherever located, is a more or less arbitrary line. Beyond its notably irregular course, the terminal moraine on the low lands about the quartzite ranges possesses no unusual features. A deep, fresh cut southeast of the lake illustrates its complexity of structure, a complexity which is probably no greater than that of terminal moraines at many points where less well exposed. The section is represented in Fig. 3. The stratified sand to the right preserves even the ripple marks which it received when deposited. To the left, at the same level, there is a body of till over which is a bed of stoneless and apparently structureless clay. In a depression just above the clay, with till both to the right and left, is a body of loam which possesses the normal characteristics of loess, both as to constitution and structure. It also contains calcareous concretions, but no shells are found.

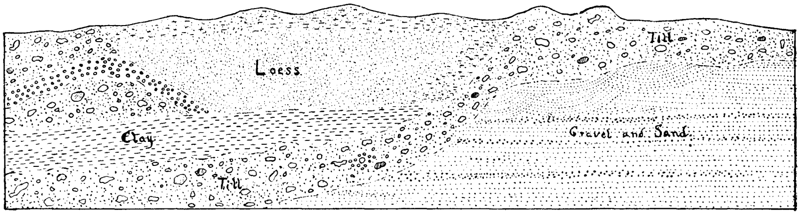

FIG. 3. Section of the moraine southeast of Devil's Lake, as exposed in a railway cut (1896).

Away from the ridges the outer face of the moraine from Kilbourn City to Prairie du Sac is bordered by overwash plains, or morainic aprons, in their normal positions and relations, except that in one locality just west of Barbaoo and south of the river, the moraine edge of the overwash plain is built up even with the crest of the moraine itself.

The margin of the ice across the quartzite range.—In tracing the moraine over the greater quartzite range, it is found to possess a unique feature in the form of a narrow but sharply defined ridge of drift, formed at the extreme margin of the ice at the time of its maximum advance. For fully eleven miles, with but one decided break, and two short stretches where its development is not strong, this unique marginal ridge separates the drift-covered country on the one hand, from the driftless area on the other. In its course the ridge lies now on slopes, and now on summits, but in both situations preserves its identify. Where it rests on a plain, or nearly plain surface, its width at base varies from six to fifteen rods, and its average height is from twenty to thirty feet. Its crest is narrow, often no more than a single rod. Where it lies on a slope, it is asymmetrical in cross section (see Fig. 4), the shorter slope having a vertical range of ten to thirty-five feet, and its longer a range of forty to one hundred feet. This asymmetrical form persists throughout all that portion of the ridge which lies on an inclined surface, the slope of which does not correspond with the direction of the moraine. Where it lies on a flat surface, or an inclined surface the slope of which corresponds in direction with the course of the ridge itself, its cross section is more nearly symmetrical (see Fig. 5). In all essential characteristics this marginal ridge corresponds with the *End-Moräne* of the Germans.

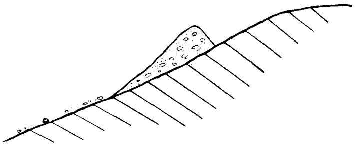

FIG. 4

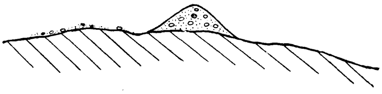

FIG. 5

FIG. 4. Diagrammatic cross section of the marginal ridge as it occurs on the south slope of the Devil's Nose. The slope below, though glaciated, is nearly free from drift.

FIG. 5. Diagrammatic cross section of the marginal ridge as it appears when its base is not a sloping surface.

For the sake of bringing out some of its especially significant features, the ridge may be traced in detail, commencing on the south side of the west range. Where the moraine leaves the lowlands south of the Devil's Nose, and begins the ascent of the prominence, the marginal ridge first appears at about the 940-foot contour (*a* Fig. 2). Though at first its development is not strong, few rods have been passed before its crest is fifteen to twenty feet above the driftless area immediately to the north (see Fig. 4) and from forty to one hundred feet above its base to the south, down the slope. In general the ridge becomes more distinct with increasing elevation, and except for two or three narrow post-glacial erosion breaks, is continuous to the very summit at the end of the Nose (*b* Fig. 2). The ridge in fact constitutes the uppermost forty or forty-five feet of the crest of the Nose, which is the highest point of the west range within the area shown on the map. Throughout the whole of this course the marginal ridge lies on the south slope of the Nose, and has the asymmetrical cross section shown in Fig. 4; above (north of) the ridge at most points not a bowlder of drift occurs. So sharply is its outer (north) margin defined, that at many points it is possible to locate it within the space of less than a yard.

At the crest of the Nose (*b* Fig. 2) the marginal ridge, without a break, swings northward, and in less than a quarter of a mile turns again to the west. Bearing to the north it presently reaches (at *c*) the edge of the precipitous bluff, bordering the great valley at the south end of the lake. Between the two arms of the loop thus formed, the surface of the Nose is so nearly level that it could have offered no notable opposition to the progress of the ice, and yet it failed to be covered by it.

In the valley between the east bluff and the Nose, the terminal moraine lies further west than on the elevations. The ice moved against the Nose from the east, and mounted to its highest point, but in this achievement it so far spent its strength as to be unable to continue, even over the comparatively level surface beyond. Divided by the Nose as by a wedge, it moved westward over the lower land on either side, but failed to occupy the intervening crest of the ridge.

In the great valley between the Nose and the east bluff, the marginal ridge does not appear. In the bottom of the valley the moraine takes on its normal form, and the slopes of the quartzite ridges on either hand are much too steep to allow any body of drift, or loose material of any sort, to lodge on them.

Ascending the east bluff a little east of the point where the drift ridge drops off the west bluff, the ridge is again found (at *d*) in characteristic development. For some distance it is located at the edge of the precipitous south face of the bluff. Farther on it bears to the north, and soon crosses a col (*i*) in the ridge, building it up many feet above the level of the bed rock. Here again, as on the Nose, the ice that had surmounted the elevation had spent its strength and was unable to move forward, even though forward movement would have been down grade.

From this point eastward for about three miles the ridge is clearly defined, the slopes about equal on either side, and the crest as nearly even as the typography of the underlying surface permits. The topographic relations in this part of the course are shown in Fig. 5.

At *e* (Fig. 2) this marginal ridge attains its maximum elevation, 1620 feet. Here again, the ice having surmounted this great elevation, the greatest of the region, was unable to move forward down the slope, although it had had energy enough to climb fully 300 feet in the last mile of its advance.

At this great elevation, the ridge turns sharply to the northwest at an angle of more than 90°. Following this direction for little more than half a mile, it turns to the west. At some points in this vicinity the ridge assumes the normal morainic habit, but this is true for short distances only. Further west, at *f*, it turns abruptly to the northeast and is sharply defined. It here loops about a narrow area less than sixty rods wide, and over half a mile in length, the sharpest loop in its whole course. The driftless tract enclosed by the arms of this loop is lower than the drift ridge on either hand. The ice on either side would need to have advanced no more than thirty rods to have covered the whole of it.

From the minor loop just mentioned, the marginal ridge is continued westward, being well developed for about a mile and a half. At this point the moraine swings south to the north end of Devil's Lake, loses the unique marginal ridge which has characterized its outer edge across the quartzite range for so many miles, and assumes the topography normal to terminal moraines. At no other point in the United States, so far as known to the writers, is there so sharply marked a marginal ridge associated with the terminal moraine, for so long a distance.

From Fig. 1 it will be seen that the moraine as a whole makes a great loop to the eastward in crossing the quartzite range. From the detailed description just given of the course of the marginal ridge, it will be seen that it has three distinct loops; one on the Devil's Nose (west of *b*, Fig. 2); one on the main ridge (west of *e*) and a minor one on the north side of the last (southwest of *j*). The first and third are but minor irregularities on the sides of the great loop, the head of which is at *e*.

The significant fact in connection with these irregularities in the margin of the moraine is that each loop stands in the lee of a prominence. The meaning of this relation is at once patent. The great quartzite range was a barrier to the advance of the ice. Acting as a wedge, it caused a reëntrant in the advancing margin of the glacier. The extent and position of the reëntrant is shown by the course of the moraine in Fig. 1. Thus the great loop in the moraine, the head of which is at *e*, (Fig. 2) was caused by the quartzite range itself.

The minor loops on the sides of the major are to be explained on the same principle. Northeast of the minor loop on the north side of the larger one (*j*, Fig. 2) there are two considerable hills, reaching an elevation of nearly 1500 feet. Though the ice advancing from the east-northeast overrode them, they must have acted like a wedge, to divide it into lobes. The ice which reached their summits had spent its energy in so doing, and was unable to move forward down the slope ahead, and the thicker bodies of ice which passed on either side of them, failed to unite in their lee. The application of the same principle to the loop on the Devil's Nose is evident.[1]

Constitution of the marginal ridge.—The material in the marginal ridge, as seen where erosion has exposed it, is till, abnormal, if at all, only in the large percentage of widely transported bowlders which it contains. This is especially true of the surface, where 90 per cent. of the large bowlders are in some places of very distant origin, and that in spite of the fact that the ice which deposited them had just risen up over a steep slope of quartzite, which could easily have yielded abundant bowlders. In other places the proportion of foreign bowlders is small, no more than one in ten. In general, however, bowlders of distant origin predominate over those derived close at hand.

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[1] It is at k, Fig. 2 that the preglacial gravel referred to in Vol. III (pp. 655–67) of this JOURNAL is found.

The slope of the upper surface of the ice at the margin.—The marginal ridge on the south slope of Devil's Nose leads to an inference of special interest. Its course lies along the south slope of the Nose, from its summit on the east to its base on the west. Throughout this course the ridge marks with exactness the position of the edge of the ice at the time of its maximum advance, and its crest must therefore represent the slope of the upper surface of the ice at its margin.

The western end of the ridge *a* (Fig. 2) has an altitude of 940 feet, and its eastern end *b* is just above the 1500-foot contour. The distance from the one point to the other is one and three-fourths miles, and the difference in elevation, 560 feet. These figures show that the slope of the ice along the south face of this bluff was about 320 feet per mile. This, so far as known, is the first determination of the slope of the edge of the continental ice sheet *at its extreme margin.* It is to be especially noted that these figures are for the extreme edge of the ice only. The angle of slope back from the edge was doubtless much less.

Devil's Lake.—At the north end of Devil's Lake, and again in the capacious valley leading east from its south end, there are massive terminal moraines. Followed southward, this valley leads off toward the Wisconsin River, and is probably the course of a large preglacial stream. It is now occupied by a small tributary to the Wisconsin, the head of which is separated from the lake by the massive moraine. To the north of the lake, the head of a tributary of the Baraboo comes within eighty rods of the lake, but again the terminal moraine intervenes. From data derived from wells it is known that the drift both at the north and south ends of the lake extends many feet below the level of its water, and at the north end, the base of the drift is known to be at least fifty feet below the level of the bottom of the lake. The draining of Devil's Lake to the Baraboo River is prevented only by the drift dam at its northern end. It is nearly certain also, that, were the moraine dam at the south end of the lake removed, all the water would flow out to the Wisconsin, though the data for the demonstration of this conclusion are not to be had. There can be no doubt that the gorge between the east and west bluffs was originally the work of a pre-Cambrian stream, though the depth of the pre-Cambrian valley may not have been so great as that of the present. Later, the valley was filled with the Cambrian (Potsdam) sandstone,[1] and reëxcavated in post-Cambrian and preglacial time. Devil's Lake then occupies an unfilled portion of an old river valley, isolated by great morainic dams from its surface continuations on either hand. Between the dams, water has accumulated and formed the lake.

While the ice was at its maximum stand, it rose above the moraine dams at either end of the lake. The melting of the ice supplied abundant water, and the water of the lake stood above its present level. The height which it attained is not known, but it is known to have risen at least sixty-five feet higher than now. This is proved by the presence of a few drift bowlders lodged on the west bluff at this height. They represent the work of a berg or of bergs which at some stage floated out into the lake.

The preglacial stream flowing through the Devil's Lake gorge.—The great gorge in the quartzite bluffs, a part of which is occupied by the lake, was a narrows in the preglacial valley. If the Baraboo was the stream which flowed through this gorge, the comparable narrows in the north quartzite range—the Lower Narrows of the Baraboo—is to be accounted for. The stream which occupied one of these gorges probably occupied the other, for they are in every way comparable except in that one has been modified by glacial action, while the other has not.

The Baraboo River flows through a gorge—the Upper Narrows—in the north quartzite range at Ablemans, nine miles west of Baraboo. This gorge is much narrower than either the Lower Narrows or the Devil's Lake gorge, suggesting the work of a lesser stream. It seems on the whole probable, as suggested by Irving,[2] that the Wisconsin River in preglacial time, flowed south through what is now the Lower Narrows of the Baraboo, thence through the Devil's Lake gorge to its present valley to the south. If this be true, the Baraboo must at that time have joined this larger stream at some point east of the city of the same name.

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[1] This fact was made known by IRVING, Geology of Wisconsin, Vol. II. Irving also advanced the explanation here given, of the lake.

[2] Loc. cit., p. 508.

Extinct glacial lake on the east quartzite bluff.—Between the arms of the main terminal moraine loop on the quartzite range, about two miles east of Devil's Lake, is a notable flat. Its location and extent are shown in Fig. 2 (*l*). With the exception of the north side, and a narrow opening at the northwest corner, the flat is surrounded by high lands. When the ice occupied the region, its edge held the position shown by the line marking the limit of its advance, and constituted an ice barrier to the north.[1] The area of the flat was, therefore, almost shut in, the only outlet being a narrow one at *h*, Fig. 2. Excavations in the flat show that it is covered with stratified sands, gravels, and clays of glacial origin, to a depth of at least sixty-five feet. If this filling were removed, the bottom of the area would be much lower than at present, and it is evident that when the ice had taken its position along the north side of the flat, an enclosed basin must have existed. Into this basin water from the melting ice flowed, forming a lake. At first it had no outlet, and the water rose to the level of the lowest point (*h*, Fig. 2) in the rim of the basin, and thence overflowed to the west. Meanwhile the sediments borne in by the glacial drainage were being deposited in the lake in the form of a subaqueous overwash plain, the coarser parts being left near the shore, while the finer were carried further out. Continued drainage from the ice continued to bring sediment into the lake, and the subaqueous overwash plain extended its delta-like front farther and farther into the lake, until its basin was completely filled. With the filling of the basin the lake became extinct. Further drainage from the ice followed the line of the outlet, the level of which corresponds with the level of the filled lake basin. This little extinct lake is of interest as an example of a glacial lake which became extinct by having its basin filled during glacial times, by sediments washed out from the ice.

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[1] The moraine line on the map represents the crest of the marginal ridge rather than its outer limit, which is slightly nearer the lake margin. Stratified drift of the nature of overwash also intervenes at points between the moraine and the lake border.

Near the northwest corner of this flat, an exposure in the sediments of the old lake bed shows the curiously contorted layers of sand, silt, and clay represented in Fig. 6. The layers shown in the figure are but a few feet below the level of the flat which marks the site of the lake. It will be seen that the contorted layers are between two series of horizontal ones. The material throughout the section is made up of fine-grained sands and clays, well assorted. That these particular layers should have been so much disturbed, while those below and above remained horizontal, is strange enough. The grounding of an iceberg on the surface before the overlying layers were deposited, or the action of lake ice may have been responsible for the singular phenomenon.

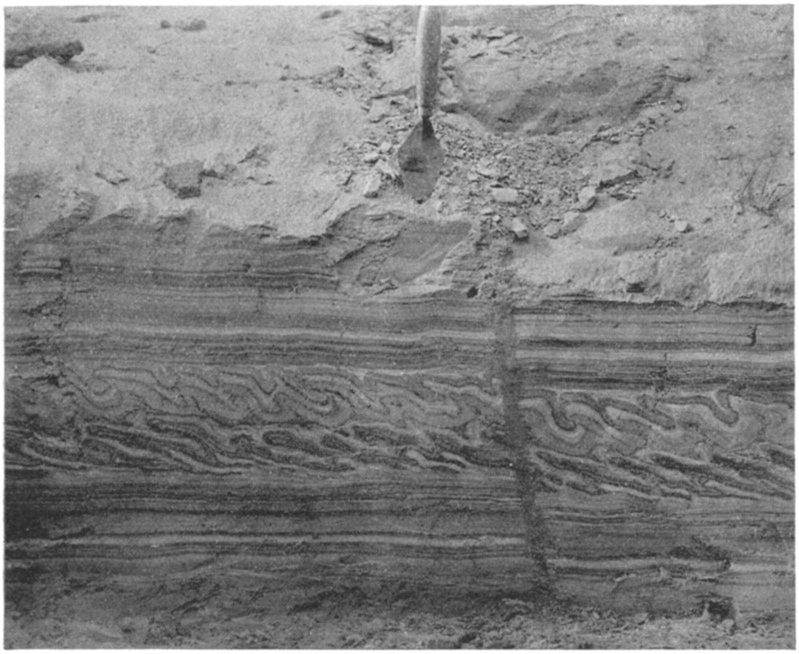

FIG. 6. Contorted layers of sand and silt, in the bed of the extinct glacial lake.

Skillett Creek.—Skirting the morainic apron or overwash plain southwest of Baraboo, is a little stream, tributary to the Baraboo, known as Skillett Creek. For some distance from its head (*a* to *b*, Fig. 7) its course is through a capacious preglacial valley. The lower part of this valley was filled with the water-laid drift of the overwash plain. On reaching the overwash plain the creek therefore shifted its course so as to follow the border of that plain, and along this route, irrespective of material, it has cut a new channel to the Baraboo. The postglacial portion of the valley (*b* to *c*) is everywhere narrow, and especially so where cut in sandstone.

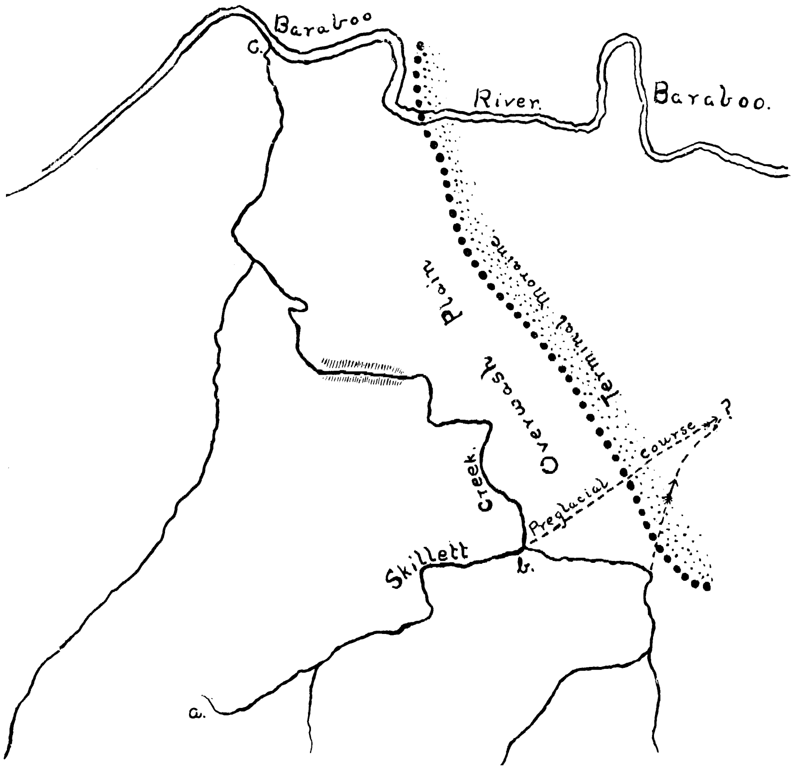

FIG. 7. Skillett Creek, illustrating the points mentioned in the text.

The course and relations of this stream suggest the following explanation : Before the ice came into the region, Skillett Creek probably flowed in a general northeasterly direction to the Baraboo, through a valley comparable in size to the preglacial part of the present valley. As the ice advanced, the lower part of this valley was occupied by it, and the creek was compelled to seek a new course. The only course open to it was to the north, just west of the advancing ice, and, shifting westward as fast as the ice advanced, it abandoned altogether its former lower course. Drainage from the ice then carried out and deposited beyond the same, great quantities of gravel and sand, making the overwash plain. This forced the stream still further west, until it finally reached its present position across a sandstone ridge or plain, much higher than its former course. Into this sandstone it has since cut a notable gorge, a good illustration of a postglacial valley. The series of changes shown by this creek is illustrative of the changes undergone by streams in similar situations and relations all along the margin of the ice.

Damming of the Baraboo.—West of the terminal moraine on either side of the Baraboo River are broad flats, extending at least as far up the stream as Ablemans. At various points, exposures show the material of the flat to be laminated clay of lacustrine type. The tributaries to the Baraboo in this region are bordered by similar flats composed of similar material. These flats, together with the flats along the main stream, represent the bottom of a glacial lake. The outlines of this lake cannot now be given. At Ablemans there is a body of loess,[1] the upper surface of which corresponds in elevation with the flat of the Baraboo below.

When the ice lay in the valley of the Baraboo with its edge just west of the city, the stream was effectually dammed. The waters which were held back by the ice dam, reinforced by the drainage from the ice itself, soon developed a lake in the valley of the Baraboo, above the point of obstruction. This body of water likewise extended up the lower course of every tributary, presumably rising until it found the lowest point in the rim of the drainage basin. The location of this point, and therefore its height, and the height of the lake when at its maximum, are not known. But at a point three miles southeast of Ablemans on the surface of a sandstone slope, water-worn gravel occurs, the pebbles of which were derived from the local rock. On the slope below the gravel, the surface is covered with loam which has a suggestion of stratification, while above it, the soil and subsoil appear to be the product of local rock decomposition. This water-worn gravel of local origin on a steep slope facing the valley, probably represents the work of the waves of this lake, perhaps when it stood at its maximum height. This gravel is about 125 feet, according to aneroid measurement, above the Baraboo River.

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[1] JOURNAL OF GEOLOGY, Vol. IV, p. 929.

This lake did not entirely disappear when the ice retreated, for the drift which the ice left, especially the terminal moraine, still obstructed drainage to the east. The moraine, however, was not so high as the former outlet of the lake had been, so that as the ice retreated, the water flowed over the moraine to the east, and drew down the level of the lake. The postglacial valley cut through the moraine is about ninety feet deep.

Besides being obstructed where crossed by the terminal moraine, the valley of the Baraboo was clogged to a lesser extent by deep deposits between the moraine and the Lower Narrows. At one or two places near the city of Baraboo, such obstructions, now removed, appear to have existed. Just above the "Lower Narrows" there is positive evidence that the valley was choked with drift. Here in subsequent time, the river has cut through the drift-filling of the preglacial valley, developing a passage about twenty rods wide and thirty-five deep. If this passage were filled with drift, reproducing the surface left by the ice, the broad valley above it would be flooded, producing a lake. At the outset, this lake must have been considerably lower than the one above the moraine to the west, but drainage from the latter into the former soon lowered the barrier between them, bringing the upper lake to the level of the lower. The lake below Baraboo was much less extensive than the one above, and probably shorter lived. It became extinct by the cutting of its outlet above the Lower Narrows down to the level of its bottom. The location of this extinct lake is shown on the map, in Fig. 1.

Other extinct lakes.—The beds of at least two other extinct ponds or small lakes above the level of the Baraboo are known. These are at *m* and *n*, Fig. 2. They owe their origin to depressions in the drift, but the outflowing waters have cut down their outlets sufficiently to bring them to the condition of marshes. Both were small in area and neither was deep.

From the foregoing it is seen that the small area centering about Devil's Lake presents a number of interesting drift phenomena, some of which are possessed of unusual significance. This is particularly true of the phenomena of the terminal moraine in its passage over the quartzite ridge, and of the phenomena which have led to the determination of the slope of the ice at its extreme edge, along the south side of the quartzite range.

ROLLIN D. SALISBURY,
WALLACE WALTER ATWOOD.